PREDICTION OF ACOUSTICAL RESPONSE OF THREE-DIMENSIONAL CAVITIES USING AN INDIRECT BOUNDARY ELEMENT METHOD

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Boundary Element Methods are numerical techniques used to implement boundary integral equations. In the past, most acoustical boundary element implementations have utilized the Helmholtz Integral Equation or Rayleigh Integral Equation. Such implementations are classified as Direct Boundary Element Methods (DBEM) since the primary variables of the problem, pressure and velocity, are directly solved. Alternatively, as Chen and Schweikert showed [1], the Huygens principle can be cast in the form of a boundary integral equation whereby the unknown variable to be solved is a ficticious boundary source distribution. Such boundary element methods are classified as Indirect Boundary Element Methods (IBEM).

It is the objective of this work to develop a technique which would characterize the acoustics of generalized cavities with the minimum model possible. Potential applications include noise source identification, influence coefficient characterization and active noise control. All boundary element methods have two advantages over finite element methods: 1) the models are smaller, and 2) the assumed variable behavior, inherent in the method to allow discretization, is harmonic rather than polynomial. Further, IBEM often requires one rather than two numerical boundary integrals as required by DBEM. Thus, a quadratic, isoparametric IBEM program was developed for this investigation. It should be pointed out that the source distribution in this solution is continuous and quadratically variable rather than continuous and constant as in Chen and Schweikert's work. The program was also formulated to include the additional capability of interior point sources and impedance boundary conditions.

To test the quadratic, isoparametric IBEM program, several simple cavity enclosure problems where studied. Results are shown in Figs. 1-3. As an aside, the program is easily converted to radiation problems. Several radiation problems were run and the results compare very favorably to numerical solutions to the Helmholtz Integral Equation found in the literature.

The IBEM methods for prediction of acoustical behavior in cavities was found to work quite well. The advantages of IBEM over DBEM or FEM are problem dependent and hence the user should be fully versed in the merits of each. However, we found that for cavity characterization where few pressures are required, IBEM seems most appropriate.

The experience with isoparametric elements suggests one other conclusion. Curved elements introduce substantial complication to the numerical evaluation of the boundary integrals. Thus, wherever appropriate, subparametric elements (i.e. elements with linear geometric interpolation and higher order variable interpolation) are recommended.

[1] L.H. Chen and D.G. Schweikert, "Sound Radiation from an Arbitrary Body," J. Acoust. Soc. Am. 35, 1626-32 (1963).

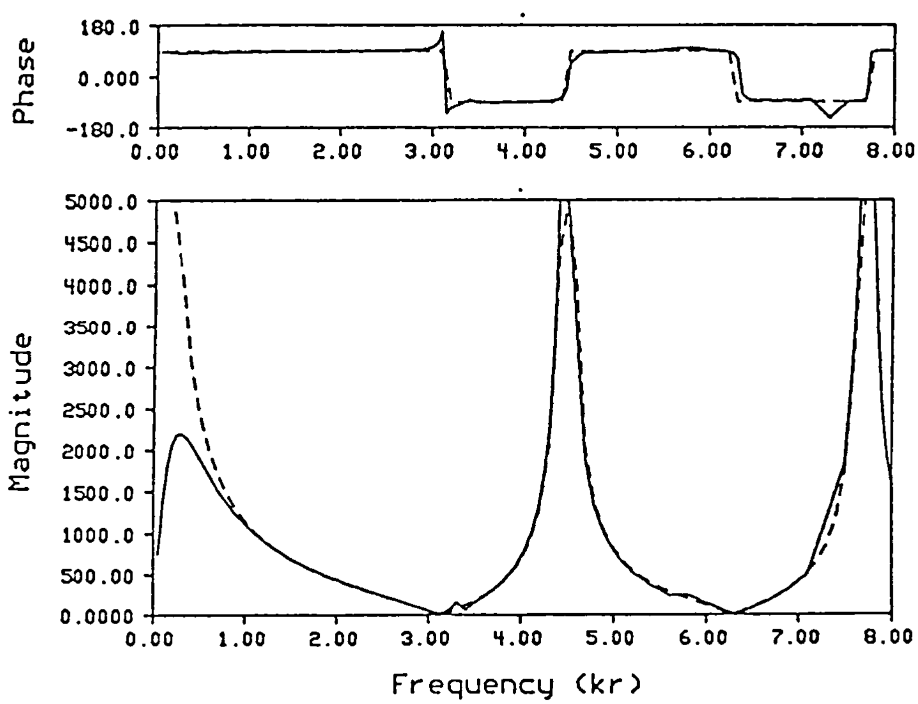

Figure 1. Spherical cavity response - pulsating sphere (r_o = .5); (---) theoretical; (———) predicted

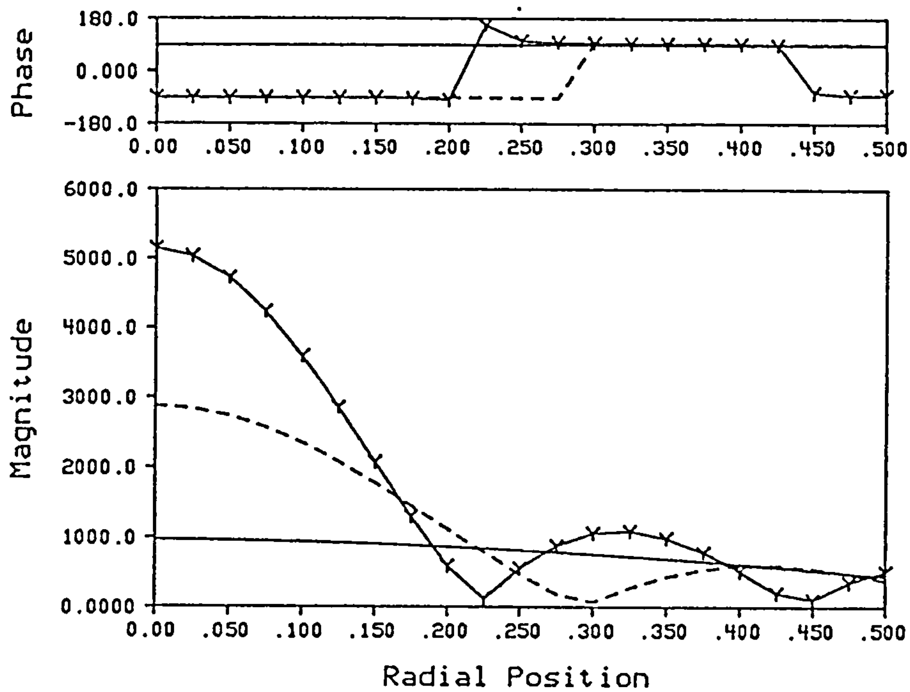

Figure 2. Pressure distribution in pulsating spherical cavity; (———) K = 4.0, (---) K = 10.8, (Y—Y—) K = 14.2.

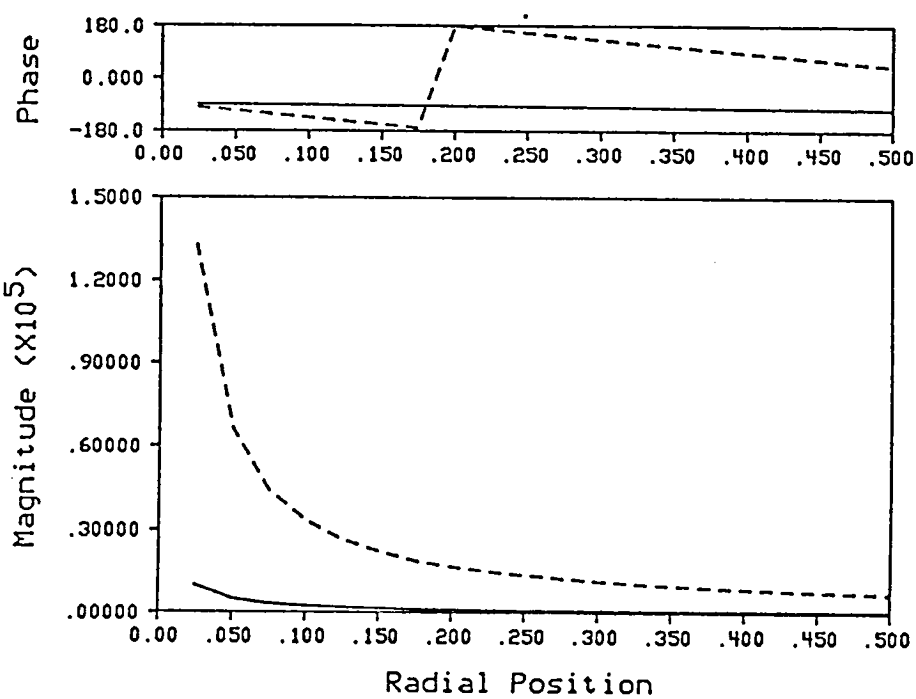

Figure 3. Response of spherical cavity with source at center and radiation boundary conditions; (———) K = .583, (---) K = 8.0.